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CALIFORNIA HYPOGAEOUS FUNGI— TUBERACEAE

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The hypogaeous fungi of America form a large, important and little known group. Practically nothing is known of the range of species or their distribution, their edibility or their life histories. Their occurrence in most cases has been noted rather by accident than through any careful or systematic search for them. In California there has been some definite attempt at extensive collection and study of the many different species.

The work was pioneered by Dr. H. W. Harkness. His work was left incomplete, however, at the time of his death and subsequently much of it was lost. It was successful in demonstrating the great variety and extent of the group. The work was then taken up by Dr. W. A. Setchell and Prof. N. L. Gardner, of the University of California, at Berkeley. The only literature available as a guide to the Californian species is the paper of Dr. Harkness, which is, unfortunately, not easily procured. The work is of little value in many ways, as the descriptions have been abbreviated. Dr. Helen M. Gilkey has made a careful "Revision of the Tuberales of California," which is an excellent account of ascomycetous forms. Drs. Zeller and Dodge have also recently published some accounts of the various Hymenogastrales in which are included numerous Californian species.

All of the recent publications will in time have to be revised more or less to include numerous additional species and allow of a modification of the published species. Aside from the paper of Dr. Harkness, there is no literature published which would be of service to the collector in the field. As in the case of the writer, the collectors must go at the work more or less blindly until experience has been gained. With all due allowances for seasonal differences, it is hoped that the following account will be of value to other collectors.

The collection of the hypogaeous fungi of the Santa Cruz Mountains, of California, is based upon a deliberate, carefully planned and systematic search. The writer has now the experience of six seasons' intensive exploration of the mountains adjacent to San Jose. It is a deliberate search that few would persist in season after season over the same ground, yet it becomes a most fascinating game at which to play.

The work begins with the coming of the fall rains and continues all through the winter months and up to the beginning of summer, when the ground becomes too dry for any fungus growths. If the ground is thoroughly covered, it frequently means the crawling into wet thickets on hands and knees and includes all the brambles, briars, poison oak and wood ticks that go along with such experiences. Sometimes the rewards from a mycological standpoint are well worth the effort. The most productive season comes in warm spring months if there has been a fair amount of rain. In some seasons there is little to be found owing to drought. Even if a goodly amount of rain has fallen and a sudden, protracted hot spell follows, the fungi will quickly disappear.

Californian Tuberaceae have been considered in the past to contain no aromatic species. Many of the species are easily detected in the soil by their conspicuous color, but some are rather difficult to find for the same reason. None were supposed to closely resemble the so-called "queen truffles" of Europe. A few resemble closely the white European species. Many are very small and a few attain to some size. Many are of no economic value, while some are large enough and abundant enough to be used for food. Some have a fine nutty flavor, others are apt to be a bit disagreeable. A small black *Tuber* has been found differing widely from any previous species found here and which developed a very strong odor. This last species was found in a spot in which I have collected different specimens every year for the last five seasons. Differing from all other previously collected forms, it turns alcohol to a deep purple color.

The methods of collecting the Tuberales and the Hymenogastreales are the same. The two groups are found frequently grow-

ing intermingled and sometimes are difficult of determination. The latter group forms a most important portion of the hypogaei. They are often large fructifications and are frequently produced in large numbers, and, above all, are strongly aromatic. These aromatic species provide a large amount of food for the rodents, the woodrats (*Neotoma*) being especially active in the search for them and leaving many signs of their work. The study of these signs is of value to the truffle hunter.

Many of the Tuberales appear to be without a conspicuous mycelium, but the Hymenogastrales are usually associated with an abundant white mycelial growth. The exposure of this mycelium will often quickly lead to the desired plants. One or two species of the Hymenogastrales are affected by parasites which leave masses of golden spores under the leaves. The presence of these spores serves as a guide to other species which are frequently associated with the host plants. Excavations made by the rodents for the different species, together with the many fragments left among the leaves, serve as an additional guide. Sometimes on warm, quiet days certain odors may be traced directly to certain species. In the end, however, instinct and experience in selecting favorable locations serve to secure the many different species, and then very often the plants appear in unexpected places where experience shows they should not appear.

Adjacent to San Jose there are ideally wooded hills of mixed oaks both in dense forest and in open scattered groups, and in other places not too far away there are fine forests of conifers and other trees which give the greatest variety of country and timber to work over. This district has been the scene of operations for the last six years. And even when one knows the ground thoroughly it is surprising how little of it may be covered on a day of good collecting. Frequently two or three hours will be spent in working over the ground under a single large oak, and on several occasions an entire afternoon has been spent in one place. The collector may pass rapidly from one place to another, as experience shows the ground to be barren, but though a place is barren one day, it may within a week or so be producing an abundance of fungi.

At Guadalupe Mines there is a spot where the ground is moist yet warm, beneath a cluster of live oaks, which every season may be depended upon to supply numerous species over a long season. As an illustration of succession of fungi that may be found and the necessity for a constant going over the same ground, my collections for this season will be of value. In November, *Hysterangium* species; January, *Gautieria* species; February, *Genea* species; March, *Tuber* species, and April, *Tuber* species and *Hydnobolites* species. All these were more or less abundant and occurred within an area of less than one hundred square feet. In other seasons this same spot has yielded many other species. In another location where intensive search was made two seasons ago with success the same ground was recently gone over with great care and tubers collected that are probably the most important yet found in the United States. At Saratoga under a single tree that produced a number of species two seasons ago there was collected in February of this year on a single day nine genera and fourteen species.

The equipment of the truffle hunter is important. I use a wheel on many trips, as the roads are excellent and the stops are very frequent in some places. It is easily hidden in the brush when I leave the roadways and take to the high hills, and it makes accessible places otherwise out of one's reach. To the wheel is strapped a small combination rake and hoe with a four-foot handle. This implement is very useful in climbing, raking and digging and furnishes good protection in a snake country, as I well know. A short-handled hoe useful for work in thick brush, a trowel, knife, tweezers, lens, kodak, plenty of newspapers and a large number of small pasteboard cartridge boxes obtained at a shooting gallery. These small boxes are very useful in handling the many small specimens or single individual specimens, while large collections are wrapped in the paper. Lunch and thermos bottle complete the outfit, and all are packed compactly in the large canvas bags used by newsboys. These bags ride comfortably with a large load evenly distributed over the shoulders.

In the earlier parts of the season the edges of the forests and the small groups of trees are usually the best places for operations, although frequently the dense forest will yield good specimens.

Late in the season the best places are to be found deep in the forest, where the ground retains more moisture. When the collector finds a favorable place for operations the rake comes into use and a small area is raked free of leaves and humus. Watch must be kept in the leaves for certain species of *Hymenogaster* and of *Melanogaster* are to be expected and occur frequently. These are dark-colored species and are easily missed. Other species will appear entirely exposed on the surface of the earth and some will be just beneath the surface and out of sight. Excavation may be continued to a depth of a foot, at which depth most species will cease to be found. Care should be taken at all stages, especially near the surface, to avoid injury to specimens, but they will often be injured in spite of it, and many of the dark-colored species will require very careful search and sifting of the soil. The rewards are more often blistered hands and an aching back than truffles, but there are also some intensely exciting moments.

Any account of the underground fungi of the state of California must of necessity be very incomplete, as a large number of the species have not as yet been determined. The large collections already listed are being continually added to with additional species and variations of the older ones. The variations alone are adding many difficulties to the work of final determination. One benefit has accrued in the many collections, and that is the large number of immature specimens which will provide valuable material for life history studies. Where there has heretofore been a very definite lack of such material, it has seemed at times more readily secured than the mature forms.

Genea compacta Hk. originally collected in Marin County, California. Rare. Ascocarps minute, 5-7 mm., reddish brown, globose with oval opening at apex protected by mass of long intermingled dark-colored hairs which arise in clusters and spread fan-like from a series of pyramidal projections arranged at regular intervals around the edge of the apical openings. Minutely and sharply verrucose. Mycelial attachment inconspicuous. Found singly and in large numbers in the vicinity of Alma, spring of 1919. In clay at a depth of over six inches and in light soil among

rocks in thick madrone forest at a depth of two inches. Not easily detected, owing to the color, which resembles the dead dry madrone leaves. Harkness describes the plant as minute, up to one centimeter. Dr. Gilkey describes it as 7–10 cm., which is, I think, an error in printing. Very few tubers reach this size. It is noticeable that the hairs protecting the apical opening to the simple cavity disappear as the plant matures and the opening is enlarged. The same arrangement is seen in another *Genea* recently collected.

Genea arcnaria Hk. described from a single collection made by Harkness. Collected subsequently by Prof. Gardner in the vicinity of Berkeley and appearing occasionally among other species in the collections made in the Santa Cruz Mountains. Not abundant, but widely scattered. Habitat favored is the moist clay soil well under large live oaks, plants appearing singly and among other species on the surface of the soil, but well covered with leaves. Ascocarps light brown, very irregularly folded, sharply verrucose; cavities are very complex owing to the folding of the tissue. Plants attain a size of 2–3 cm. in favorable seasons. Very difficult to see in the ground, as the color often blends with the debris on the surface where it appears. Care is necessary in collecting to avoid damage to specimens growing close to the surface of the soil. A faint brown mycelium is evident around the base of the plant, but is very much localized.

Genea Harknessii is widely distributed and very common early in the season. Ascocarps small, black and more or less simple and globose to occasional specimens very complexly folded. Sharply verrucose to the touch, appearing in groups on the surface of the soil well under leaves, under all kinds of shrubs, abundant in old trails and roads overgrown with *Baccharis* sp. Plants are often missed or damaged unless care is taken to avoid the soil surface with the excavating implement. It has been found here on the surface of the ground without leafy covering, on the edge of a hard-beaten road under madrones. Also found in leafy humus under *Arctostaphylos* sp.

This species has a very distinguishing feature in its earlier stages in the presence of a white floccose mycelial covering, enveloping the entire plant, and with hyphal threads penetrating the chambers.

It is not to be seen in old specimens and very quickly disappears after the plants are taken from the ground. Whether this is a parasite is yet to be determined, but the mycelium of the species is scant and dark colored. I find, however, nearly all plants have this covering, while it is not to be seen in other species so far collected.

Genea Gardnerii appears rarely among the specimens of *G. Harknessii*, but usually somewhat later in the season. It is so close in resemblance to the former species that it is difficult to determine offhand. It is black, verrucose and more complexly folded. It appears on the surface of the ground, but well covered with leaves and in places similar to the preceding form.

Genea cerebriformis is collected over wide areas throughout a very long season. It appears in all kinds of soil, but more abundantly in clay soil under oaks. Over one hundred have been collected in the month of January in wet clay soil and in the same ground again in April. Plants are minute, usually under one centimeter, but some of nearly 2.5 cm. have been recently found. The plants are white, rarely simple and globose, but more often a formless mass of complex chambers. Usually found below the surface to a depth of one to three inches, but are rather conspicuous in spite of the very small size. Recent specimens were found to have a very strong odor and to depart radically in size from the description.

Hydnотrya ellipsospora is described from a single collection made in 1909 at Pacific Grove by Prof. N. L. Gardner. It was again reported in March, 1917, when several plants appeared in collections made here. From these the original descriptions were verified. The type of this species is very small, but subsequent collections over four seasons have proven that the type is not representative of the size of the species. It appears in all localities under numerous trees and in various ways. The fresh plants are a very delicate purple color with a delicate "peach bloom" on the surface. This color very rapidly fades and in two or three days is gone, the plants becoming a dull brown. It is frequently found in soft, moist earth at a depth of several inches, but the plants are small. They are often very complexly folded, with very large

empty cavities. The flesh is very much like certain forms of *Peziza*. At Alma under pines there were collected a dozen plants in the month of March in very wet ground. These plants were all partly exposed at the surface of the ground and without any leafy covering. The plants in this collection were all over five centimeters in size and one measured nine centimeters in its largest diameter. At Saratoga the species was found under a great depth of humus and again proved to be of very large size, 7 cm., and still later in the season it was found at Guadaloupe Mines in open rocky ground under oaks. While numerous smaller plants fully matured have been found, these large plants seem to be very common, in so far as this rather rare species may be called common. I think, from my experience, that the plant is widely distributed and abundant in moist years and is rare only for lack of those to collect it. This is large enough and abundant enough to be of value for food purposes, although it is not aromatic.

Tuber californicum is widely distributed and in some seasons very abundant, especially under oaks in moist clay soil. It is to be found on the surface of the soil or just below the surface. Many specimens are to be had by raking over the leaves of solitary oaks or on the edges of oak forests. Frequently the species attains a size of four or five centimeters, which is rather larger than described. It is white and very conspicuous, globose or roughly lobed, frequently irregular in shape and is sometimes deeply cracked in developing. The gleba is at first white, but later appears to be brown. This effect is seen as the spores arrive at maturity, when it appears to be filled with tiny grains of pepper. Its maturity is detected without the aid of a lens. Although this species is edible, it is a trifle astringent to the taste. Aside from this it has no particular flavor. One of the difficulties in collecting this plant for food is the fact that small slugs attack it in its early stages and riddle the gleba, leaving in the end only the peridium as an empty shell. Nematodes and larvae of a tiny black fly also infest the plants once they are opened by the slugs. At Alma I have found dozens of the small immature plants in very wet soil early in the season, but later, when they should have reached maturity, not one plant could be seen. Spore dispersal is secured by means of the slugs.

Tuber candidum is the most commonly collected and widely distributed truffle in this State. It is particularly abundant in some seasons in wet clay soil at the Guadalupe Mines, generally under the live oaks, but frequently under other trees. It appears late in the winter and continues into the late spring or early summer. April and May seem to produce the greatest amount of mature plants. In places where it is collected in abundance one year it seems to be three or four seasons before it occurs in any large amounts again. The ascocarps are very smooth, pale brown or with a slightly pinkish color, or sometimes, when young, of a dark gray. It is variable as to color and shape. Generally globose or with two or three large lobes, it is sometimes found with deep furrows traversing the surface; occasionally it is cracked to a depth of several millimeters. The peridium is thick, the gleba is at first white, turning to a pale purple color and finally a rich brown, with a tinge of yellow as it reaches maturity, and the yellow spores fill the tissue. The asci may be seen for a long time during the development of the ascocarp, but the spores are slow to mature. In the middle of March I examined a certain piece of ground and found it barren. Two weeks later I collected a pint of mature specimens in it, and repeated two weeks later with some very large specimens. At the next visit, two weeks later, nothing was to be seen but a few empty peridia left by the slugs.

Plants are rarely on the surface of the soil, but are just beneath and down to a depth of several inches, and are easily raked up, but care must be used to avoid damaging them or missing them altogether if they are not abundant. Usually they are rather conspicuous if reddish brown, but if very pale or dull gray they are hard to find. Frequently single plants appear over wide areas, but generally they are in considerable numbers in a small area. They frequently are found in clusters of three or four plants, appearing to arise directly from the spores without any great mycelial growth.

The mycelial growth seems to be very scant and the plants show no basal point of attachment. Many specimens show where loose, fine hyphae traverse the surface of the ascocarp, but these disappear when the plants are removed from the ground. The dis-

persion of the spore is secured by the slugs that infest the plants and also by the rodents that sometimes use them for food. The plants have no odor, but are rather nutty of flavor and are abundant enough to be useful for food. Specimens this year have measured over three centimeters, which is larger than described for the species.

It has been found abundantly in one vineyard near the Guadeloupe Mines, and at Alma I found some fine large plants among the grass roots in a pasture adjacent to live oaks.

Tuber lignarium, or what has passed for that species, as collected in this district is perhaps the most interesting form so far collected. Described originally as *Terfeziopsis lignaria* by Dr. Harkness, the collector, it has been recently placed in the genus *Tuber* by Dr. Gilkey on a very careful study of the original collection. In its general appearance it is very close to *T. candidum*. The plants found here differ somewhat from the description of the type, although they have the typical spores with the recurved spines. During the past season it has proven more abundant than *T. candidum* and is to be found over a wide area and over a long season.

Considering its previous appearance in but one collection its occurrence here is of exceptional interest. In the spring of 1917 a small dark brown tuber, always immature, appeared in collections made all through this district. Plants occurred in all kinds of ground and under many trees, but generally in association with the oaks. Plants are uniformly a dark brown with areas of a lighter color where the venae externae open to the surface. The plants appeared in abundance on the warm upper slopes of the hills, where the growth is more open and the soil moist and light. Plants are found close to the surface, but usually down to a depth of three or four inches.

A long drought occurred and tubers of all kinds were very scarce until the winter of 1918-19. This drought was broken by a prolonged storm early in September of 1918. Over twelve inches of rain fell in three days at the Guadeloupe Mines. Following this rain there came a warm, humid spell lasting over a month, which was ideal for the growth of fungi. On the

27th of September, in an old road well covered with leaves, I collected about a dozen small brown tubers fully matured and growing closely together on the surface of the ground. These were typical specimens of *Tuber lignarium* on the appearance of the spores. The same conditions repeated to some extent in November, 1920, and mature tubers were again collected in the same place. These tubers had fully matured since the rains ceased on the 12th of the month.

In February of the present year the same brown tubers began to appear under the oaks, and in March they were to be found everywhere on the warm upper hillsides, and in April they reached the greatest abundance and maturity. Many of these plants reached a size well over 2 cm. They are very rough in appearance, generally globose or very much lobed, occasionally flattened with the venae externae converging at the apex. The peridium appears to be rough without being verrucose; the tissue of the gleba is at first white, then becoming a faint purple, and finally brown as the mature spores appear all through the tissue. It is very much like *T. candidum* in taste and is without odor. There is very little sign of any mycelium and no point of attachment visible. Plants examined in the ground show only a few fine threads traversing the surface of the plant. Frequent clusters of four plants are found together, apparently arising from spores in the same ascus. In cases like this there is a development of one plant at the expense of the others, it seemingly absorbing its food from the surrounding moist ground, so that one will hardly grow at all, the next but little, the third less than average, while the one may be considerably above the average.

Geopora Harknessii occurs regularly in the winter and early spring in some abundance usually under the pines all through the mountains. I have found it rarely under the oaks. Globose or irregular in shape, roughly folded tissue, with a very dark brown tomentose peridium and reaching a size of 4-5 centimeters if conditions are favorable. The plants are not easily seen under the wet leaves owing to the color. Frequently found on the surface of the ground, but well covered with the pine needles, but very often is to be collected in clay soil fully exposed at the surface.

Hydnотryopsis Setchellii is one of the rarest forms found. It was described from one of the Harkness collections and not reported again until found with other rare forms at Guadalupe. The plants are small and of a clay color with a white gleba. Found in wet clay soil at a depth of three inches. Material collected here was sufficient to verify all details of the descriptions which were made from long-preserved material. There have been some additional collections and one that would indicate that the species attains a size of over three centimeters.

Delastria rosea has been collected twice, once in an earthy pocket among rock ledges under laurel and once this last season under pines. It is a small inconspicuous plant tinged with red and resembles very much one of the small rosy-colored Hymenogasters. It is, in spite of its color, a very rare and difficult plant to collect. The last collection was made in a bed of purple mycelium which was producing a large amount of a species of *Elaphomyces*. To be expected under all kinds of trees.

Hydnobolites californicus occurs in abundance apparently under all kinds of trees and begins to develop very early in the winter and remains up till the first of June. Very slow in maturing and quickly riddled by the slugs. It appears in a vein of coarse white mycelium, to which it is attached by a long, thick rhizomorph, which breaks away very easily. The point of the attachment is easily seen, however. It is a dirty white, compactly developed globose or irregular ascocarp without a thick protecting peridium as in the various species of *Tuber*. The venae externae open in numerous places to the surface and are very conspicuous in the young plants. It becomes dry and gristly in age, turning to a light brown color.

Several large plants collected late in the season possessed a very strong musty odor without being in any way decayed. These were found in a bed of mycelium about two inches below the surface of the soil under oaks. As the plants matured they pushed farther toward the surface and finally were severed from the mycelium altogether as they reached the surface of the soil, where they were covered very slightly with dry leaves.

Pseudobalsamia magnata occurs early in the season in wet clay

soil under oaks and pines, usually at a depth of one or two inches, in close association with a conspicuous mycelium, and usually with a large number of plants in close relation, although not seen in clusters. Although the plants are, as a rule, less than two centimeters in size, they are conspicuous in color and easily seen. Plants more or less globose or flattened at the apex where the venae externae converge. The peridium is sharply verrucose, somewhat variable in color, gleba white with large asci and spores easily identified. Some plants collected in May and June of this year appear to be this species, but were larger and of a very bright orange color.

A variety of this species, var. *nigra*, has been collected rarely and is little known. What has appeared to be this form appears scattered and solitary on the surface of the ground under laurels. A recent collection of what appeared to be this species, however, gives asci and spores of a very distinct nature and is probably a distinct species, although the general shape is typical of the species.

Pachyphloeus citrinus is not at all well known and the collections are all referred with some doubt. It has appeared twice during the last season in ground that has been searched for the last six years. Just under the surface of the soil under oaks and *Heteromeles* sp. The surface of the plant is covered with minute warts, is of a dark red color, with several folds near the base, a definite mycelial attachment. Plants are globose and with a very deep opening at the center of the apex where the venae externae converge. The tissue of these plants was blood red.

Elaphomyces variegatus is found at various points pretty well buried in the loose soil. It appears in a conspicuous bed of yellow mycelium and is at maturity a large yellow plant very conspicuous in appearance. It is found from January to June following the moisture zones down the hillsides in dense forests. It develops from two to ten inches deep in the soil and reaches a size of 3-4 centimeters, and is globose, roughly warted, with large cells filled with a colorless tissue making up the gleba. The asci dissolve at a very young stage. In maturity the gleba becomes a powdery dark mass of spores resembling a form of *Scleroderma*.

Endogone macrocarpa occurs in many places as isolated plants,

but occasionally a considerable number will be found several inches deep in the soil under an oak. The plants are dirty white or tinged with a faint rosy color at first, globose, 1-2 cm. in size, and when cut open have the appearance of being filled with grains of sand. In one place I have watched for three seasons for a recurrence of hypogaei under an oak where this form was found in considerable abundance in March, but nothing of any kind has been found that would throw light upon the future development of this species.

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